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ABSTRACT

Two experiments involving 42 students from the Model Secondary School for the Deaf investigated both the visual and tactile components in the processing of spatial information. Test measures used were the Figures Rotations Test, Group Embedded Figures Test, and Tactile Rotations Test. The study suggested that spatial reasoning is a determining factor in several areas of cognitive growth, that this ability may follow a developmental learning pattern, and also that the symbolization process may be enhanced and developed by spatial reasoning learning. (SBH)

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AN INVESTIGATION OF THE VISUAL AND TACTILE SPATIAL REASONING ABILITIES OF THE HEARING IMPAIRED/DEAF STUDENT

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This study is part of a longitudinal research project to investigate and understand the development of the cognitive structures of the hearing impaired/deaf student. Underlying the philosophical foci of the research project is what has been called a "cognitive approach" to understanding the processing of information in an academic environment. A "cognitive approach" implies that learning from instruction is more productive if it is studied as an internally cognitive mediated process rather than as a direct product of the environment, people, or factors external to the learner. This approach involves understanding the relations or interactions between the learner's cognitive processes and aptitudes, such as attribution, motivation, encoding, memory, cognitive styles, and cognitive structures, and the characteristics of instructional treatments (Wittrock, 1978).

A large corpus of research by H.A. Witkin, in evaluating and measuring cognitive structures, has led him to propose a model for viewing human information processing. This theory has at its base the construct of "differentiation". Differentiation is conceived as incorporating both the psychological, social, and the neurophysiological domains of an individual. This construct is a particularly appropriate framework for investigating the different components that comprise the "cognitive approach" to research in education.

A central component in Witkin's model of differentiation is the field-dependent/field-independent dimension. This dimension is conceived as a tendency of an individual to rely on internal or external referents in information processing, relative to a broad spectrum of cognitive, social, and psychological functioning. The field-dependent and the field-independent construct is considered to be one expression of a general individual difference dimension.

Spatial reasoning is one of the basic factors of measurement in assessing the field-dependent and the field-independent dimension. Differences in spatial abilities correlate with a person's ability to structure or restructure different tasks within areas of the cognitive domain. Spatial reasoning ability seems to be a related factor in different areas of cognitive, social, and psychological functioning (Witkin, 1962). Witkin suggests that field-dependence/field-independence (as evidenced by a variety of spatial measurement instruments) appears to be a more important factor in understanding the many different areas that make up the cognitive structures of an individual whether it be mathematical, language, or problem solving in the social environment.

Although the concept of spatial reasoning has been described as one of the crucial components of cognition, research in this area with the deaf/hearing impaired individual has been limited and sometimes confounded by being subsumed under the general construct of perception. The construct of spatial reasoning as presented in this paper is concerned with conceptual and representational space and not with perceptual space. It has been suggested that one of the major obstacles to spatial abilities research is that the mental processes involved in spatial performance are not understood and that spatial skills involve more than space perceptual ability. What is implied in this context, by spatial reasoning, is the mental manipulation of visual configurations as wholes or gestalts as opposed to the analysis of different figural details.

A cognitive task has both a perceptual and a production component. An individual must both perceive and act upon a specific stimulus in order to perform a higher level cognitive task such as problem solving. In measuring spatial reasoning, what is being tapped is the production and not the perceptual component of cognition.

Cross cultural studies have shown significant differences in spatial reasoning abilities between different groups of people pointing to the influences of both the physical and social environment on the development of this ability. Factors such as child rearing practices, teaching content and techniques, length of education, nutrition, and the demands of the physical environment have all been suggested as factors that influence the development of spatial reasoning abilities (Mitchelmore, 1976).

Language differences between cultures was found to be related to differences in spatial reasoning abilities. Two different views can be hypothesized to account for this. One, the Whorfian hypothesis that we dissect nature along lines laid down by our native language; and two, that a people's language expands to match the perceptual differentiation which is important in their society. The second hypothesis appears to be more consistent with the recently projected theories of differentiation in perceptual learning (Mitchelmore, 1976). The developing corpus of research in spatial reasoning skills continues to indicate a close tie between language factors, social factors, and physiological factors showing that spatial reasoning abilities are developed through an individual's experience. Although this ability is only one aspect in the development of a person, it is an important and perhaps crucial base to a well integrated cognitive structure that can effectively process information whether visual-spatial, verbal, or numerical.

Piagetian theory suggests that spatial representations are built up through the process of organization of actions and or logico-mathematical experiences as space is both physical and logico-mathematical in nature. Whether logico-mathematical spatial concepts and physico-spatial concepts develop in interaction or autonomously but correspond structurally has yet to

be established. Strong evidence, however, suggests that the two factors are closely integrated in the cognition of an individual and that form and content of mathematics instruction play an important role in developing spatial reasoning skills (Montangero, 1979).

Also evidenced by research is the role of language processing in the development of mathematical abilities. The sequential reasoning necessary in mathematics may be closely related to the sequential processing of verbal information. The role of language in the development of mathematical conceptualization has yet to be fully explored. Some evidence exists, relative to the interfaces of the two cognitions. A need for developmental readiness is suggested by Professor Godsave, who states that, "a child needs a good grasp of several basic linguistic structures in order to do even minimal evaluation of early math concepts" (Godsave, 1978). Godsave also suggests that the different sense modalities (auditory, visual, tactile) play an important role in the extraction of perceptual information in mathematics. Beginning insight as to how the mobile and visual processes contribute to the learning of linear or distant measurement exist. But the importance and role of the auditory process in the mathematical conceptualization learning process has not been researched. It is suggested that the mobile experience with the environment provides the basis for linear or distance measurement but the assimilation-accommodation process is visual and perhaps even tactile. Because the deaf/hearing impaired child must depend primarily on his/her visual and tactile senses to a greater degree than the hearing child, a different cognitive conceptualization of the spatial process may develop.

Tomlinson-Keasey and Kelly's research gives support to this thinking. These researchers hypothesize that because of the "limited accessibility to

auditory symbols during the prelinguistic years, the deaf child may develop an information processing system that is significantly and systematically different from that of hearing children" (Tomlinson-Keasey, 1978). In their thinking, the kinds of symbols the child has available to attach to objects during the prelinguistic period of development determines the symbolic models the child will use for the later learning of new concepts. Because of the language problem a majority of deaf children may have either no, or an inconsistent symbol system modeled or shared with them during the critical language acquisition years. If the information processing system and the symbolic world of the deaf/hearing impaired child is developed differently then the cognitive structures may also be special and particular. If this is true, what implications does this have for the development of spatial conceptualization skills which depend on the symbolization process?

One discipline which has been shown to be strongly related to spatial reasoning abilities is mathematics. Research evidence suggests that spatial factors are significantly correlated with achievement in mathematics, especially in mathematics where the concepts are essentially spatial in nature (Hills, 1957). Spatial ability also seems to have a determining effect on a student's aptitude for mathematics. Mathematics is here defined as a special kind of language in which we communicate by means of written signs or symbols ideas which are esentially geometrical or spatial, that is, a visual rather than a verbal language (Smith, 1965).

A distinction can be drawn in mathematics between computation learning and problem solving skills. Mathematicians have suggested that although calculation is an indespensible component to mathematics, it is not mathematics. It is when children are first brought beyond the sphere of elementary calculation

to the stage of problem solving that mathematical abilities are tapped. Dr. I. Scheffler (Victor I. Thomas, Professor of Education and Philosophy, Harvard University) suggests that geometry may be, in the sequence of math education in most schools, the first time that the student comes into contact with the kinds of problems that really tap mathematical aptitude and ability. In discussing the skills needed for competency in mathematics, specifically geometry, he ties different kinds of mathematical skills to neurophysiological factors:

> Certain sorts of injury to the brain may, for example destroy the capacity to read while leaving intact the ability to recognize pictures, though both capacities are visual. To what extent does success in geometry depend upon pictorial, as distinct from linguistic processing capacities? In what ways indeed is a diagram like and unlike a picture? A map? and equation? A word description?

Scheffler feels that an insight into the cognitive processing of geometric information is important in understanding the particular skills needed for both language and mathematical reasoning (Scheffler, 1976).

Because in the deaf/hearing impaired student the visual-spatial and the verbal domains may follow a different pattern of development relative to the type, use, and structure of language(s) employed, assessment of the abilities of the hearing impaired student maybe impeded by the language development differences. Spatial reasoning assessment, appears on the surface, not to be language dependent and as such may provide an important and more accurate insight into the cognitive abilities and the thinking processes of the deaf/hearing impaired student.

Research in mental imagery, has posited a "deep" and "surface" structure in the processing of mental images. This structure is similar to the hypothesized "deep" and "surface" components of language. Further suggested by this research is the hypothesis that any aspect of this internal representation of

the mental image, whether it be of the nature of deep or surface structure must correspond to some physical process in the brain (Shepard, 1978). Shepard thinks that "mental rotation" (a spatial reasoning skill) is one aspect of the imagery thinking process. He defines "mental rotation" as the study of mental operations on objects in space. His research suggests that in performance of spatial reasoning tasks, requiring mental rotations, the individual develops "an internal analog of the corresponding physical transformation," and it is this analog which provides the individual with accurate or inaccurate information. For Shepard, there are both logical and analogical processes of thought, and that although the analogical processes are often neglected in psychological research, they may be of equal importance to the logical processes in understanding the cognitive structures of an individual. Spatial reasoning plays an important role in the development of analogical processing skills.

Researchers have theorized three major spatial factors; space, spatial orientation, and visualiation. The space factor is defined as the ability to perceive spatial patterns accurately and to compare them with each other. Spatial orientation is that which involves a person's ability to remain unconfused by the varying orientations in which a spatial pattern may be presented. And visualiation is the ability to comprehend imaginary movement in three-dimensional space or the ability to manipulate objects in imagination (French, 1951).

This study is comprised of two parts: one, a visual-spatial processing component and a tactile-spatial processing component. Most experiments on concept formation or identification of geometrical shapes and sizes are done only in terms of visual clues. As earlier discussed in this paper, the role of the other sense modalities (tactile, auditory) have been implicated in the

learning of spatial information. This study is an attempt to investigate both the visual and the tactile components in the processing of spatial information. The visual-spatial component of the study investigates two factors of spatial reasoning as hypothesized by Hill; space (figure rotations test) and spatial orientation (embedded figures test). The tactile-spatial component measures the student's ability to do some of the same problems that he/she had previously done in the visual mode, in a tactile mode, without the assistance of vision. The tactile-spatial evaluation is a pilot investigation of this sense modality, and has thus far only been studied with a small sample group of students.

This research study asked the following questions:

1. Do the two different instruments measure different factors of spatial reasoning ability (space and spatial orientation)?
2. Are there differences in spatial reasoning ability between students who elect to take geometry and students who chose a standard math class?
3. Within these two groups (geometry and math) is there a difference between the male and female student?
4. Do the two spatial tests (GEFT and FRT) correlate statistically?
5. Is there a relationship between the visual and the tactile domains relative to a spatial reasoning task?

Method

Visual-Spatial Component

Subjects:

A total of 32 students (18 male; 14 female) participated in this part of the study. All the subjects are students at the Model Secondary School for the Deaf, Gallaudet College, Washington, D.C. The mean age of the students was

17.8 years (s.d.=2.1). The average hearing loss (PTA) was 85.84 (s.d.=13.5). The students were drawn from five classes at the MSSD; three classes of Math 101-2 (Mathematical Skills) and two classes of Math 301 (Geometry).

Tests:

The tests used to assess spatial reasoning abilities were; one, Figure Rotations Test (space factor) and Embedded Figures Test (spatial orientation factor).

Figure Rotations Test (FRT)

This test was developed and has been used extensively by Dr. G. H. Wheatley, Chairman, Department of Mathematics, Purdue University, in research with hearing subjects. It has not been used with deaf/hearing impaired students. This instrument consists of 20 items. The task requires the student tested to use a cognitive process of mental rotation through an arc of prescribed direction and degree. Each item presents the subject with a two dimensional shape and five possible choices. The individual is asked to choose one shape from the choices, that with rotation on the single plane, would be an exact replica of the item presented. When given to hearing subjects the test was timed for five minutes. In the administration of the test with the hearing impaired subjects an additional two minutes was allowed. The maximum score on the test is twenty.

Group Embedded Figures Test (GEFT)

The GEFT is a test which measures a person's ability to locate a previously seen simple figure within a larger complex figure which has been so organized as to obscure or embed the simple figure. The test measures a person's competence at perceiving shapes or figures as discrete from the whole form in which they are embedded. Competence at disembedding is associated with

competence at disembedding in non-perceptual problem solving tasks. The corpus of research relative to this test strongly suggests that this instrument meaures a certain self-consistency within the individual that extends to different areas of body concept, sense of self, personality control, and defense mechanisms. These are the domains that fall under the construct of "differentiation." It appears that competence in disembedding crosses modalities. Extremely high correlations have been found between the visual GEFT situation and both tactile and auditory disembedding tasks (Witkin, 1971). Further, this perceptual ability also seems to exist in persons in whom a given sense modality has been lacking from birth onward, as with a deaf person or with a blind person (Fiebert, 1967). The Group Embedded Figures Test that was used in this study is an adaptation of the original individually administered Embedded Figures Test. The items selected for the GEFT were based on an item-analysis study. The test contains 18 complex figures or spatial shapes of increasing complexity.

Procedure

The students were tested in their individual classroom areas. In the administration of each test, the task and the instructions were explained to the students by this researcher and an assistant with the aid of a 3'x 4' flannel board. Replications of the shapes in the test example were made and used on the flannel board to assure that the student understood the task and the language of the test booklet. The instructions, explanation, and demonstration were all given in sign language (total communication mode).

Results

The following Table 1 shows the mean scores for the total group of students on the GEFT and the PRT separated according to sex.

Table 1

Mean Scores for Male and Female on the Group Embedded Figures and Figure Rotations Test

	Males			Females			
Test	n	M	SD	n	M	SD	F
Embedded Figures	18	6.00	(5.28)	14	5.43	(4.11)	1.65
Figure Rotations	18	13.00	(7.09)	14	15.36	(3.20)	4.90**

**p < .01 two-tailed

The male and female students differed significantly on the FRT ($p < .01$). This difference, however, did not carry over to the GEFT ($p < .36$) which did not show up significant relative to sex.

The following Table 2 gives the mean scores for the total group of students on the GEFT and the FRT separated according to the different type of mathematics class.

Table 2

Mean Scores for Group I (Math) and Group II (Geometry) on the Group Embedded Figures and the Figure Rotations Tests

	Group I (Math)			Group II (Geometry)			
Test	n	M	SD	n	M	SD	F
Embedded Figures	15	2.93	(2.52)	17	8.24	(4.89)	3.77**
Figure Rotations	15	12.80	(6.39)	17	15.12	(5.09)	1.57

**p < .017 two-tailed

The GEFT showed up as being significantly different ($p < .01$) between the group of students who chose geometry and the group of students who chose math. The performance between the two groups was not significantly different on the Figure Rotations test.

To determine the strength of association between the two spatial reasoning instruments a Pearson product-moment correlation was computed. The correlation coefficient between the GEFT and the FRT was 0.348; significant ($p < .025$).

A two-way analysis of variance was done to see if the groups (math and geometry) differed on each of the two tests (GEFT and FRT). Also whether the males and females performed differently and if there was an interaction effect. Tables 3 and 4 present the results of the ANOVA. No signfiicant interactions were found for the FRT. The GEFT, however, showed a significant interaction ($p < .001$) between sex and group.

Table 3

Two-way Analysis of Variance
Figure Rotations Test (FRT)

Source of Variation	df	SS	MS	F	P
Main effects	2	80.82	40.41	1.21	.31
Sex	1	38.01	38.01	1.14	.29
Group	1	37.06	37.06	1.11	.30
2-way interactions	1	20.20	20.20	0.60	.44
Sex x Group	1	20.20	20.20	0.60	.44
Residual	28	929.94	33.21		
Total	31	1030.96	33.25		

Table 4

Two-way Analysis of Variance Group
Embedded Figures Test (GEFT)

Source of Variation	df	SS	MS	F	P
Main effects	2	231.15	115.57	6.99	.003**
Sex	1	7.14	7.14	0.43	.51
Group	1	228.58	228.58	13.84	.001**
2-way interactions	1	2.40	2.40	0.14	.70
Sex x Group	1	2.40	2.40	0.14	.70
Residual	28	462.44	16.51		
Total	31	696.00	22.45		

**Significant

Tactile Spatial Component

Subjects

Ten students (4 male; 6 female) participated in this part of the study. All the subjects are students in the same art class at the Model Secondary School for the Deaf, Gallaudet College. The mean age of the students was 17.1. The average hearing loss (PTA) was 85.5.

Test

The Figure Rotations Test and the Group Embedded Figures Test was administered to the students as a group in their classroom. The same procedure was utilized as was used in the visual-spatial part of the study. A random sampling of seven of the 20 items on the FRT was then developed. Three dimensional wooden replications of each test item were made. The wooden models were exact proportional representations of the paper and pencil test item. Each spatial shape was fixed (glued) on a plywood board (2' x 4') so that the rotation angle

could not be altered. The design, outline, and assembly of the tactile models were supervised by an instructor in the woodworking shop at the MSSD, Dan Devine.

Two months after the students had taken the FRT and the GEFT, testing with the tactile replications was begun. Students were tested individually in a separated section of the large art room. The subject sat next to a large table that had a low, smaller table on top. Each tactile item was slipped under the smaller table. The student could not see the tactile board. Three minutes was permitted for each problem. The student could keep his/her eyes open; and was permitted to use both hands if so desired. The intructions for the test as well as, the answer to any questions the student had before starting the test were given in sign language (total communication mode). The researcher administering the test sat opposite the subject and recorded on paper the answer the subject gave to each item.

Results

The following Table 5 gives the results of the three tests; GEFT, FRT, and TCRT (Tactile Rotations Test). No significant differences were found between this small group of males and females on any of the three tests.

Table 5

Mean Scores for Males and Females on the GEFT, FRT, and TCRT Tests

	Males			Females				
Tests	n	M	SD	n	M	SD	F	p (two-tailed)
GEFT	4	7.50	3.51	6	8.33	5.35	2.32	.51
FRT	4	13.00	8.04	6	16.67	5.28	2.32	.38
TCRT	4	5.00	1.63	6	4.50	2.07	1.61	.73

Correlation coefficients were computed for the three tests. Table 6 shows the results.

Table 6

Correlation of the GEFT, FRT, and TCRT

TESTS	FRT	TCRT
GEFT	.39	.21
FRT		.64**

**p < .02

The visual-spatial and the tactile component of the Figure Rotations Test (FRT) showed a significant correlation ($p < .02$).

Discussion

The results of this study appear to support some of the theoretical research constructs relative to the functioning and the development of spatial reasoning abilities. Research studies have noted sex differences in the hearing community on spatial reasoning tests. This has been supported by research with the deaf/hearing impaired student (Parasnis & Long, 1978). The results of this study partially support the sex-difference hypothesis. For in a comparison of the mean scores for males and females relative to the two spatial reasoning instruments, a significant difference ($p < .01$) was found for the Figure Rotations Test (FRT). This difference did not show up for the Group Embedded Figures Test (GEFT). This result differs with the result reported by Parasnis and Long for the same test (GEFT) which showed up as

significant in their study. (Although two other tests of perceptual spatial skills used in their study did not prove to be statistically significant.)

A significant difference did appear in this study relative to the GEFT when the subjects were separated by mathematical groups. The GEFT showed a significant difference ($p < .01$) between Group I (Math) and Group II (Geometry). No significant difference was noted for the FRT. It would thus appear from the results of this study that spatial ability as measured by the GEFT is related more to level of achievement in mathematical reasoning rather than to sex. The two spatial reasoning instruments used in the visual-spatial component of this study proved to be statistically correlated ($p < .025$). The differences between the instruments relative to group and to sex suggest that the two tests may be measuring different factors of spatial ability (space and spatial orientation); and that these factors may be related to level of development in spatial reasoning ability.

Van Hiele, a Dutch mathematician, has suggested that a developmental learning pattern exists with respect to the acquisition of spatial reasoning skills. In his thinking these levels are related and inherent in the development of thought processes. Van Hiele feels, as evidenced by Russian research, that the passage from one level to another is not a spontaneous process concomitant with a student's biological growth and age but that this change is basically under the influence of learning and therefore dependent on the content and methods of instruction (Wirszup, 1976). If one accepts this paradign for learning of geometric concepts, and if geometric learning is tied to spatial reasoning skills, then the techniques and materials used in teaching geometric concepts becomes a crucial area of mathematical learning.

One can hypothesize that the level of skill being tested by the FRT; the factor of space, was a level that had been achieved by both groups of students. The level of skill being tested by GEFT; the factor of spatial orientation, was a level that had been achieved only by Group II (Geometry) students, and not by Group I (Math) students.

The tactile-spatial component of this study showed no significant difference between the male and female students in this group. The correlation coefficients computed for the three different tests: GEFT, FRT, TCRT showed a significant correlation between the FRT and the TCRT. Research in this component is presently continuing. The size of the reported sample is too small for this researcher to make any statistical inferences.

It has been suggested in this study that spatial reasoning is a determining factor in several areas of cognitive growth; and that this ability may follow a developmental learning pattern. Also that the symbolization process may be enhanced and developed by spatial reasoning learning. Symbolic reasoning is an important component of our cognitive structures. The ability to develop an internal analog of corresponding physical transformation and to manipulate that analog in our cognition is a crucial thinking process. Spatial reasoning appears to play a significant role in the development of analogical thinking. The importance of the analogical mode of thought, its relationship to spatial reasoning, and the role of these two components in the development of the cognitive structures and processes of the deaf/hearing impaired student needs more intensive and extensive research.

References

Deregowski, J. B. Pictorial recognition in subjects from a relatively pictureless environment. African Social Research, 1968, 5, 356-364.

Fiebert, M. "Cognitive styles in the deaf" Perceptual and Motor Skills, 1967, 24, pp. 319-329.

French, John W. The Descriptional Aptitude and Achievement Tests in Terms of Rotated Factors. Chicago: University of Chicago Press, 1951, pp. 236-247.

Gibson, E. J. Principles of Perceptual Learning and Development. New York: Appleton-Century-Crofts, 1969.

Godsave, Bruce F. "Language and experience for fundamental mathematical concepts" Teaching English to the Deaf, Gallaudet College, Vol 5, No. 1, Spring, 1978.

Hills, John R. "Factor analyzed abilities and success in college mathematics." Educational and Psychological Measurement, XVLL, No. 4, Winter, 1957.

Hudson, W. The study of the problem of pictorial perception among unacculturated groups. International Journal of Psychology, 1967, 2, 90-107.

Mitchelmore, M. C. "Cross-cultural research on concepts of space and geometry," Space and Geometry: Research Papers ERIC/SMEAC, August, 1976, pp. 143-173.

Parasnis, I. & Long, G. L. "Relationships among spatial skills, communication skills, and field dependence in deaf students" Paper series #28, NTID, Rochester, N.Y.

Montangero, Jacques, "Recent research on the child's conception of space and geometry in Geneva: Research work on spatial concepts at the International Center for Genetic Epistemology" in Space and Geometry-ERIC/SMEAC, August, 1979.

Olson, D. R. Cognitive Development: The Child's Acquisition of Diagonality. New York; Academic Press, 1970.

Scheffler, Israel "Basic mathematical skills: Some philosophical and practical Remarks" Teachers College Record. Vol. 78, No. 2, December, 1976.

Shepard, Roger N. "The mental image," American Psychologist, February, 1978, pp. 125-137.

Smith, Ian McFarland Spatial Ability, San Diego: R. R. Knapp, 1965.

Tomlinson-Keasey, C., & Kelly, R. R. "The deaf child's symbolic world," American Annals of the Deaf, Vol. 123, No. 4, June 1978.

Wheatley, G. H., Willis, I. G., & Mitchell, O. R. "Cerebral processing of spatial and verbal-analytic tasks: An EEG study, (in press), West LaFayette, Indiana. Purdue University, 1978.

Witkin, H. A., Dyk, R., Goodenough, D. R., & Karp, I. A. Psychological Differentiation, New York: Wiley, 1962.

Witkin, H. A., Oltman, P. K., Raskin, E., & Karp, I. A. A manual for the Embedded Figures Tests, Palo Alto, California, Consulting Psychologists Press, 1971.

Witkin, H. A., & Beverly, J. W. "Psychological differentiation in cross-cultural perspective, "Journal of Cross-Cultural Psychology, 1975, 6, pp. 4-87.

Witkin, H. A. & Goodenough, D. R. "Field dependence revisited," Research Bulletin Educational Testing Service, Princeton, New Jersey, 1976, December.

Wirszup, Izaak "Breakthroughs in the psychology of learning and teaching geometry" University of Chicago. Space and Geometry: Papers from a research workshop ERIC/SMEAC, August, 1976, pp. 75-97.

Wittrock, M. C. "The cognitive movement in instruction," Educational Psychologist, 1978, 13.